Peer Review of Lawrence Berkeley National Laboratory (LBNL) Study on Direct Current in the Data Center

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Agenda

- Introduction, background and goals
- LBNL project goal summary
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  - Goal 4: Development of DC power
- 380Vdc use cases
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- Summary
- Discussion

LBNL = Lawrence Berkeley National Labs

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Introduction and Background

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- All costs are rising for data center owners; efficiency is more and more important
- In Januar 2007, LBNL posted the results of their demonstration project studying 380Vdc power in the data center
  - http://hightech.lbl.gov/documents/DATA_CENTERS/DCDemoFinalReportJan17-07.pdf
- Many numbers have been quoted from the report – what do they all mean?

- The Green Grid goal:
  - Provide a review of the study
  - Provide additional, relevant facts to allow any data center owner to make an analysis on what is best for their future
  - Clarify the 5-7% energy savings gain posted by LBNL should be the relevant discussion, not the 28% compared to a typical AC system

Please note, in this presentation and paper :

- AC is alternating current
- DC is direct current (not data center)

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LBNL Project Goals

The following were the stated goals of the LBNL project:

1. *Show that [380V] DC-powered server(s) exists in the same form factor or can be built*
2. *Show that [380V] DC-powered server(s) provides the same level of functionality*
3. *Measure and document any efficiency gains from the elimination of multiple conversion steps in the delivery of [380V] DC power to the server hardware*
4. *Identify areas requiring further development or follow up investigations*

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Goal 1: Form Factor

Show that [380V] DC-powered servers exist in the same form factor or can be built.

LBNL

- Project determined:
  - Only change is to individual server power supply units
  - 380Vdc power supplies fit into similar or smaller space
- For the study, standard AC PSUs were modified to demonstrate the feasibility

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Agree with LBNL. Additionally:

- Modifications to the power supplies consistent with what would be required for a commercially available product
- Even though 380Vdc PSUs could be smaller, the system space will still be needed to accommodate AC PSUs
- Only if manufacturers go "all DC" can the space be reallocated

PSU = Server Power Supply Unit

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Goal 2: Functionality

Show that [380V] DC-powered servers provide the same level of functionality.

LBNL

Compute functionality in workloads showed no difference between AC and 380Vdc

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Agree with LBNL. Additionally:

Power variation and quality functionality needs to be specified for PSU specifications

- No data exists for PSU inlet variability
- Currently, issues can only be dealt with through design and prediction
- 380Vdc PSU and bus specifications will need to be developed before wide implementation

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Goal 3: Efficiency Gains

Measure and document any efficiency gains from the elimination of multiple conversion steps in the delivery of [380V] DC power to the server hardware.

LBNL

- A 380Vdc system was successfully built and tested based on goals 1 and 2
- A reduction in power consumption of 5-7% was measured between the built 480Vac and 380Vdc systems

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- It wasn't the goal of LBNL to make the most efficient system, but:
  - When comparing efficiencies, similar comparisons should be made
  - Data has often been misquoted, leading to misunderstood conclusions
- Lots of good work, but a few notable areas provided efficiency losses
  - Neither UPS can be considered "best in class"
    - AC UPS was 89% efficient
    - DC UPSs were 92% and 94% efficient
  - AC UPS was 208V and DC UPS was 480V
    - 480V is more efficient that 208V by 1-3%
  - Placement of transformer for AC system

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Goal 3: Efficiency Gains

Author	480-208Vac Best Practice	380Vdc	Difference	References
LBNL DC system A vs AC system B @ ~30% load	79%	87%	8%	1
LBNL DC system B vs AC system B @ ~30% load	79%	85%	6%	1
Pratt @ 50% load	68%	74%	6%	2
Rasmussen @ 50% load	84%	88%	4%	3
The start and end points of the power path vary between each study, which is the major reason for the variation in efficiencies.				

In review of the LBNL study, as well as the other references, The Green Grid concludes that an end user could obtain an improvement of 4-6% efficiency points over well designed efficient 408-208Vac systems available today

1. Tschudi, et.al. "DC Power for Improved Data Center Efficiency." Lawrence Berkley National Labs, January 2007
2. Pratt, Annabelle, et. al. "Evaluation of 400Vdc Distribution in Telco and Data Centers to Improve Energy Efficiency." *Intelec*, 2007
3. Rasmussen, Neil. "APC White Paper #63 Rev. 5 - AC vs. DC Power Distribution for Data Centers." 2007, http://www.apc.com/wp?wp=63

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Goal 4: Development of DC Power

Identify areas requiring further development or follow up investigations.

LBNL

- Many challenges are associated with bringing this technology to market, all listed in report
- Further work needs to be done looking at this

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Agree with LBNL. Additionally:

- Availability of 400Vdc rated UL489 circuit breakers
- Connector interlocks
- Breaker coordination and over current protection
- Personnel training for facility level work at 380Vdc

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380Vdc Use Cases

380V dc – where and when would it be effective to use in the near term?

- Poor or negative TCO
  - Replacing power distribution of an existing 480Vac data center
  - Retrofitting 380Vdc at the rack level
  - New facility without UPS
  - Addition of 380Vdc to existing 480Vac facility
- Potential deployment opportunity
  - Extensive retrofit (including UPS) of whole facility
  - Brand new facility
    - Should have the ability to procure a smaller number of different model 380Vdc servers
    - Should be a large data center where 4-6% savings has a big impact

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Additional Information

The Green Grid paper lists additional useful technical information from LBNL and others on the following topics:

- Modification of power supplies
- Equipment loads
- Derivation of AC to DC loading ratio
- Input current distortion
- Tare losses of flywheel
- Nominal capacities of equipment
- Load point
- Efficiency curves
- Power supply and transformer efficiencies

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Summary

- LBNL and its partners successfully completed a demonstration of 380Vdc power
- 380Vdc power can make a difference in certain applications
  - Challenges remain before this will be commercially viable
- Be knowledgeable of all the architectures available to choose the one best for *your* needs

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